The Green and Golden Bell Frog *Litoria aurea* — from riches to ruins: conservation of a formerly common species

Ross L. Goldingay

Department of Biological Sciences, University of Wollongong, Wollongong, New South Wales 2522.
Present Address: Faculty of Resource Science and Management, Southern Cross University,
Lismore, New South Wales 2480.

ABSTRACT

The Green and Golden Bell Frog Litoria aurea was considered a common frog in New South Wales about 20–30 years ago but it has suffered a major contraction in geographic range and a decline in abundance, indicating it is vulnerable to extinction. It is presently listed as Threatened in New South Wales where protection by the *Endangered Fauna (Interim Protection) Act* 1991 (now the *Threatened Species Conservation Act* 1995) has required surveys of its distribution and abundance and some research in order to prepare management plans for development sites that it occupies. Its listing in New South Wales has stimulated other research and monitoring that are not related to development consent. Given its threatened status in New South Wales where the majority of its historic range occurs, it is deserving of protection by the Australian *Endangered Species Protection Act* 1992. This paper presents a preliminary recovery plan that directs further research and describes a strategy for managing populations of the species. This strategy requires conservation of several *L. aurea* populations in each region throughout its geographic range. This recognizes the importance of maintaining any existing genetic diversity that may be present among populations but also recognizes the need for several viable populations within a region to minimize the threat of catastrophes extinguishing the small populations that are now characteristic of *L. aurea*.

INTRODUCTION

A critical component of any conservation programme is the preparation of a recovery plan for each species that is listed as endangered. Recovery plans describe the tasks that are considered necessary to halt a species' decline and encourage recovery to the extent that a listed species can be delisted (ANCA 1994; Caughley and Gunn 1995; Tear *et al.* 1995). Recovery plans require detailed information on the biology of endangered species in order to be effective. However, few such species have been adequately studied when they are first listed (Tear *et al.* 1995). Thus, often a considerable amount of time and money is required to obtain information that is pertinent to a species' recovery. In the USA it takes an average of nine years to formulate recovery plans for federally-listed endangered vertebrates, by which time these species are at a greater risk of extinction than at the time of their listing (Tear *et al.* 1995). This suggests that an outline of tasks tailored to the recovery of a particular species should be articulated as early as possible to facilitate the process.

The Green and Golden Bell Frog *Litoria aurea* was listed on the revised Schedule 12 (the endangered species list) of the New South Wales *National Parks and Wildlife Act* 1974 following enactment of the New South Wales *Endangered Fauna (Interim Protection)* Act 1991 and retained the highest conservation category status (Threatened) when Schedule 12 was further revised (gazetted on 12 December 1992). It has maintained its status on the recently (December 1995) enacted *Threatened Species Conservation Act* 1995 that has replaced the interim Act in New South Wales. Despite this conservation status in New South Wales, where more than 80% of its geographic range occurs (see Cogger 1992), there has been no recognition of this species' vulnerable situation from the Commonwealth Government.

The aims of this paper are to review the conservation status of *L. aurea*, consider whether it deserves federal listing as an endangered species and to describe the issues that are relevant to a recovery plan.

DISTRIBUTION AND ECOLOGICAL REQUIREMENTS

The historic geographic range of *L. aurea* extended from East Gippsland in Victoria, north to approximately Byron Bay in northeastern New South Wales (Cogger 1992) and west to Bathurst and Tumut (Moore 1961). It has been introduced to New Zealand, New Caledonia and the New Hebrides (Tyler 1979). This species was formerly described as a common frog (Cogger 1960; Barker and Grigg 1977; Tyler 1992) but recent surveys in New South Wales have shown a substantial contraction of its range and an associated decline in its abundance (see White and Pyke 1996). In contrast, recent surveys in

Victoria suggest that there has been no apparent change in population size or distribution (Gillespie 1996).

The preferred habitat of *L. aurea* has been described as vegetation besides permanent water such as streams, swamps, lagoons, farm dams and ornamental ponds (Barker and Grigg 1977; Cogger 1992). Recent observations in Sydney have shown that artificial habitats are quite important and have been responsible for the persistence of this species in many areas (Greer 1994; Cogger 1993a; White and Pyke 1996). Ephemeral ponds that are free of predatory fish appear essential for successful breeding (Pyke and White 1996) because fish are significant predators on the eggs and tadpoles of *L. aurea* (Morgan 1996; T. van de Mortel, pers. comm.; A. White, pers. comm.).

It appears that the decline of *L. aurea* in New South Wales is an indicator of the destruction and degradation of a particular ecosystem or habitat type in eastern New South Wales. Pyke and White (1996) suggest that the habitat requirements of *L. aurea* in New South Wales and Victoria differ due to the use of disturbed sites and breeding largely in ephemeral ponds in New South Wales, compared to the use of sites with little human disturbance and commonly breeding in permanent ponds as well as ephemeral ponds in Victoria. However, White and Pyke (1996) document the degradation of many natural sites that were occupied historically by *L. aurea*. It appears that the frequent use now of artificial or disturbed sites is because this is all that remains of its former breeding habitat or that is not occupied by predatory fish.

Many sites where *L. aurea* occurs are characterized by the presence of ephemeral ponds with an abundance of Cumbungi *Typha* spp. and a surrounding area of grass (Pyke and White 1996; Goldingay, pers. obs.). Cumbungi may not be a requisite habitat component (e.g., Cogger *et al.* 1993a); ponds may occasionally contain other aquatic vegetation such as *Eleochaeris, Juncus* and *Phragmites* (Pyke and White 1996; W. Osborne, pers. comm.). Cumbungi may be preferred because it provides a suitable diurnal refuge and foraging area for frogs. Non-emergent aquatic plants may be required for deposition of eggs during spawning (G. Daly, pers. comm.; T. van de Mortel, pers. comm.) and may provide some refuge for tadpoles from fish (Daly 1995; Goldingay, pers. obs.). Grassy areas may be used for foraging and shelter by metamorphlings and juvenile frogs (Goldingay, pers. obs.).

Sites with *L. aurea* often contain additional refuge sites such as piles of rubble (Cogger *et al.* 1993a; Greer 1994) which may be used for hibernation. Frogs may use areas of natural bushland for foraging when it occurs in close proximity to wet habitat and may seek shelter among vegetation or litter to hibernate. Where suitable habitat occurs in close proximity to houses, *L. aurea* may shelter in garden vegetation close to small ornamental ponds (Cogger *et al.* 1993a; Goldingay, pers. obs.). Despite the need for much more detailed information on the use of habitat by *L. aurea* there is sufficient information now on the habitat requirements of *L. aurea* to begin managing its populations (see Fanning and White 1994; Pyke and White 1996).

PLANNING POLICIES AND ENDANGERED SPECIES LEGISLATION

In New South Wales, there are two *State Environmental Planning Policies* (SEPP) that have provided various degrees of protection to the habitat of *L. aurea*. Nominated coastal wetlands are protected under SEPP 14 and such areas may contain *L. aurea*. An example of the ineffectiveness of this State policy to protect a population of *L. aurea* is discussed by Daly (1996). Nominated areas of urban bushland in the Sydney and Lake Macquarie regions are protected under SEPP 19. One example where this policy has provided some protection to a population of *L. aurea* is that at Roberts Road, Greenacre, in Sydney's south-west (see White 1993). Here, remnant bushland covering approximately 1.7 ha has been listed under SEPP 19 and contains cumbungi habitat along two water channels, in addition to dense stands of Paperbark *Melaleuca* spp. In short, both policies have provided limited protection to the habitat of *L. aurea* and are unlikely to be more effective because many areas where *L. aurea* occurs are not worthy for nomination under either policy.

The *Endangered Fauna (Interim Protection) Act* 1991 (EF Act) in New South Wales has provided important short-term protection for endangered fauna such as *L. aurea*. The introduction of the EF Act resulted in complementary changes to the *National Parks and Wildlife Act* 1974 (NPW Act) and the *Environmental Planning and Assessment Act* 1979 (EPA Act). These changes necessitated a review of the endangered fauna species listed by the NPW Act which led to the inclusion of *L. aurea*. Due to the EF Act, it is now standard procedure to determine whether endangered fauna are likely to be present at development sites when development applications are to be lodged with a local council. If such fauna are present, then a determination is required of whether the proposed development is likely to significantly affect (previously defined in the EPA Act but now defined in the *Threatened Species Conservation Act* 1995) their environment. If it will, then a *Fauna Impact Statement* (FIS) (previously defined in the NPW Act but now defined in the *Threatened Species Conservation Act* 1995 as a *Species Impact Statement*) is to be prepared. In short, this leads to the preparation and implementation of a management plan for the development site. Occasionally, this may also provide important research and monitoring of the endangered fauna.

Several FIS's that deal primarily with *L. aurea* have been prepared for proposed developments in Sydney. The FIS for a proposed development at Rosebery concluded that the frog population could not be maintained on site in the long-term due to low numbers and low genetic variability (Cogger *et al.* 1993a; Threatened Species Unit 1994a). It was considered desirable to use animals from this site for captive breeding purposes so that they could be later used in a relocation programme. A management plan has been prepared for this population that includes interim on-site management, description of the captive breeding programme that has been initiated at Taronga Zoo with animals derived from the Rosebery site, and a description of the relocation programme (Fanning and White 1994). Considerable progress has been made to implement this management plan (Gunninah 1995a). Two sites within 10 km of Rosebery have been selected for frog relocation and rehabilitation of existing habitat at these sites has commenced (Gunninah 1995b). The latter has involved the construction of ponds specifically for *L. aurea* at one site. At the other site, rotenone will be used to eliminate mosquito fish from existing ponds.

Another FIS (White 1993) considered a development proposal for land adjacent to the remnant bushland at Greenacre (see above). This FIS provided recommendations that should protect the water quality at this site and increase the area of cumbungi habitat. The development approval for this site requested the preparation of a long-term management plan that would include research on the population ecology of the local population and some documentation of the use of habitat away from the water channel (Threatened Species Unit 1994b).

The presence of *L. aurea* at the Sydney Olympic development site (Homebush Bay) required an FIS (Greer 1994) which proposed the following studies: 1. detailed ecological studies including assessment of the habitat requirements of the present population, 2. continued monitoring of the distribution and abundance of frogs in the local area, 3. creation of habitat away from the development site to replace that which would eventually be destroyed and, 4. a genetic study of the species from a variety of sites. The first three studies were included in the development approval for the site (Threatened Species Unit 1994c) while the fourth was included with another study and has been completed (Threatened Species Unit 1994a; Colgan 1996).

A fourth FIS considered the impact on *L. aurea* of proposed activities associated with extending a colliery in the Hunter Valley (Threatened Species Unit 1995). This development was approved subject to: 1. further surveys to identify all sites of potential habitat; 2. enhancement of potential habitat; and 3. creation of artificial habitat. Disturbance of an occupied site will not be permitted if artificial habitat cannot be shown to be self-sustaining for at least three years (Threatened Species Unit 1995).

For each of the above developments, the NSW National Parks and Wildlife Service has issued permits that allowed the developments to proceed. Translocation of *L. aurea* from the subject site was approved in two cases. At Rosebery, the population was assessed to be too small to be viable while at Homebush Bay, sufficient land was available to create habitat away from the specific development site. Further research and monitoring will occur at three of the sites (Threatened Species Unit 1994b,c, 1995).

An assessment at the site of a proposed housing development near Port Kembla in Wollongong containing *L. aurea* concluded that a FIS was not required (Mills and Associates 1994). Such a conclusion is in stark contrast to the preparation of an FIS at other development sites where *L. aurea* has been found, although a small quarry occupied by *L. aurea* at Port Kembla (2 km from the other site) was recently (late 1995) filled in without any formal assessment of the site. A management plan for the housing development site was prepared that provides protection to frog habitat on-site and requires further monitoring of the frog population at the completion of the development. In this instance there may be little incentive for these recommendations to be implemented because they are not governed by the formal FIS procedure.

It is important to note that the above protection of *L. aurea* habitat, introduction of site-specific management plans and funded research and monitoring, would not have occurred in the absence of the EF Act. Moreover, legislation by the Federal Government and other state governments to protect endangered species do not provide equivalent short-term protection (e.g., Wilson and Clark 1995). One reason for this is that the definition of "take" (i.e., an activity directed towards an endangered species that is prohibited under most endangered species Acts) in the EF Act includes habitat modification. This is not included in other Acts that protect endangered fauna in Australia but whose emphasis is on the preparation of long-term management (i.e., recovery) plans for endangered species.

Recovery plans will be constrained by available funding and priorities given to listed species based on their perceived vulnerability or public appeal. This is a major criticism of the implementation of the *Endangered Species Act* 1973 in the USA (Rohlf 1991). The requirement under the NPW Act (brought in with the EF Act) for the preparation of an FIS, places the onus of preparing (and funding) a management plan on the developer of a site (see Threatened Species Unit 1994a, b, c, 1995) and does not assign priority ranking to any listed species. Therefore, short-term protection is provided to all species until a more carefully considered management plan or recovery plan can be prepared for each species.

To ensure appropriate long-term protection *L. aurea* should be listed as vulnerable by the Australian Commonwealth's *Endangered Species Protection Act* 1992. A species is defined as vulnerable by this legislation "if, within the next 25 years, the species is likely to become endangered unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate" (ANCA 1994). Species listed as endangered are considered in immediate danger of extinction. *Litoria aurea* has declined throughout 80% of its range in the last 20–30 years. A species that has declined so precipitously must be considered vulnerable if not endangered, unless the threatening factors have been fully identified and neutralized. For *L. aurea,* this is not the case (see below) so it must be considered a suitable candidate for becoming endangered "within the next 25 years". It would be naive to believe that the threatening factors operating in New South Wales will not spread into Victoria where populations of *L. aurea* apparently have not shown any decline.

RECOVERY PLANNING

Recovery plans describe the actions that must be followed to achieve the recovery of endangered species. For many species, this involves a plea for detailed research to be conducted into their ecological requirements, for a thorough assessment of their distribution and abundance, and for the need to preserve viable populations of each species (e.g., Cogger *et al.* 1993b; Webster *et al.* 1995). For *L. aurea,* it is possible to provide a much more detailed account of specific actions that should be followed in order to prepare a recovery plan.

Ecological Requirements

Much information has been collected on the ecological requirements of *L. aurea* in the last few years (see above) but much more is required for long-term conservation of this species. For example, adult *L. aurea* may occur at a distance away from wet habitats (White 1993; Murphy 1995) but the reasons for this are not clear. Future studies into the ecology of *L. aurea* should document the following: 1. assessment of habitat use for feeding, breeding, shelter and hibernation; 2. assessment of the movement of individual frogs as it relates to feeding, breeding and dispersal; and 3. habitat requirements of metamorphlings and juvenile frogs.

Distribution and Abundance

Further surveys are required to adequately describe the distribution of this species. White and Pyke (1996) have provided a comprehensive account of the present distribution of this species but additional locations are being discovered each year. Surveys should therefore be concentrated in areas of apparently suitable habitat where the species has not been found. This will be useful in identifying areas that are suitable for habitat rehabilitation and reintroduction (see below).

The development of a standard methodology (e.g., Heyer *et al.* 1994) to describe the abundance and determine the presence of *L. aurea* at occupied sites (e.g., a minimum of three nocturnal counts of calling males at sites on warm nights after heavy rain) should be attempted. This is an important consideration given that surveys for this species may often provide negative results at sites where it is known to occur (White 1993). Failure to develop such a methodology will hamper population studies that are needed to assess population viability (see below).

Threats to Recovery

Identifying the causes of decline for an endangered or threatened species is possibly the most important step to be taken in conserving such species and an experimental approach is strongly advocated (Caughley 1994; Caughley and Gunn 1995). Although all factors responsible for the decline of *L. aurea* have not been identified, two major factors have been identified: predation by the introduced Mosquito Fish *Gambusia holbrooki* and loss of suitable habitat. There is very good evidence now implicating the mosquito fish in the disappearance of *L. aurea* in many areas. Experiments in the lab and in the field have shown that these fish readily feed on the eggs and tadpoles of *L. aurea* (Morgan and Buttemer 1996; T. van de Mortel, pers. comm.; A. White, pers. comm.). Also, assessment of sites with *L. aurea* has shown a greater frequency of breeding in ponds where predatory fish (mostly *G. holbrooki*) were absent (Pyke and White 1996). Studies in the USA and Europe have also shown that there is a highly significant negative association between the presence of predatory fish and the ponds and lakes used by frogs for breeding (Bradford 1989; Bradford *et al.* 1993; Bronmark and Edenhamn 1994). Further field studies at sites occupied by Mosquito Fish where *L. aurea* continues to breed may provide management insights.

Controlling the impacts of Mosquito Fish predation is desirable to safeguard many remaining populations and to allow recolonization of apparently suitable habitat. At present, there are several ways to achieve this: 1. builders lime (which will be toxic for approximately one month) can be used to poison mosquito fish (Barlow *et al.* 1990) present in ponds at a time when *L. aurea* is not present (e.g., during winter); and, 2. ponds can be constructed (see also Pyke and White 1996) that will dry out during part of the year (by limiting the depth of the pond) and therefore should not be colonized by the Mosquito Fish which is a live-breeder that will not survive desiccation.

The loss of suitable breeding habitat will continue to be a problem for *L. aurea* because many suitable breeding sites occur in areas that are now desired for development in Sydney and Wollongong and presumably elsewhere in coastal New South Wales (see above). This highlights a need to begin managing occupied sites more purposefully for *L. aurea* but also to begin to identify sites of suitable but presently unoccupied habitat.

The habitat of *L. aurea* may be rendered unsuitable by factors such as water pollution. Many occupied sites in New South Wales occur in close proximity to housing or industry and are therefore potentially subject to wastes that may alter the quality of the water. Management of these sites will require close attention to ensure that the existing water quality does not decline. Research should examine the effects of changed water quality on tadpole and adult survival.

The disappearance of *L. aurea* from some locations where Mosquito Fish are absent (e.g., the southern tablelands: Osborne *et al.* 1996) indicates the presence of other threatening factors that have not been identified. Van de Mortel and Buttemer (1996) provide compelling evidence that UV-B radiation is not responsible. One possible threat to the recovery of *L. aurea* is predation by cats and foxes. Domestic cats are known to feed on frogs (Paton 1990) and given the location of many *L. aurea* populations within urban areas, cat predation could potentially pose a threat. Foxes have been reported taking *L. aurea* (Daly 1995) and may pose a significant threat to many frog populations outside of Sydney. The impact of these predators requires investigation. If cats and foxes are significant predators on *L. aurea*, then education of cat owners close to frog populations may be needed but in areas where foxes are a problem, a baiting programme may be necessary. Given the apparent small size of most *L. aurea* populations (White and Pyke 1996), road mortality (see Daly 1995) could present problems for recovery in some instances.

Preservation of Viable Populations

Too little is known about the population ecology of *L. aurea* to be able to make any assessment of what would constitute a viable population. Censuses of numerous populations show that most are characterized by very small adult population sizes (<20 individuals) (White and Pyke 1996). This is intriguing given the extremely high fecundity of *L. aurea* (see van de Mortel and Buttemer 1996). Further monitoring of several populations is required to better understand the dynamics of *L. aurea* populations. Information on population structure (number of males, females, adults, subadults) and on mortality rates at several sites is required. Such information will be critical to conducting a Population Viability Analysis (PVA) for *L. aurea*. This will be an important part of the recovery planning to ensure that viable populations are secured.

Despite this lack of information to define a viable population at present, it is known that viability of vertebrate populations is related to population size (e.g., Berger 1990) so efforts should be directed at preserving the largest populations of *L. aurea* that are known, as well as giving consideration to increasing the available habitat at other sites to allow populations to increase. Many of the existing populations in Sydney have only small areas of habitat available to them. This may be due to the presence of the Mosquito Fish in larger habitat areas. Removal or elimination of fish from large habitat areas is one way to ensure much larger population sizes of *L. aurea* than have currently been observed. This may be difficult to achieve and a more realistic goal may be to construct ephemeral ponds close to large habitat areas to provide suitable breeding sites. This should enable adult frogs and metamorphlings to use aquatic vegetation around large ponds for foraging and shelter.

Translocation

The transfer of endangered fauna from one site to another has been widely practised in Australia in recent years to resolve conservation problems but there are no cases involving frogs (see Serena 1994). Amphibian translocation in North America has been reviewed by several authors recently. Dodd and Seigel (1991) suggested a lack of success based on one example while Burke (1991) and Reinert (1991) cite several examples to counter the argument. For *L. aurea*, deliberate introduction to New Zealand, New Caledonia and the New Hebrides (Tyler 1979) demonstrates that translocation can be successful for this species.

Litoria aurea is a very suitable candidate for translocation; it has a high fecundity and spawn masses can be collected (see van de Mortel and

Buttemer 1996) and tadpoles readily raised to a metamorphling stage. These small frogs (or even large tadpoles) can be easily dispatched to sites with suitable but unoccupied habitat. This can be used to increase local population sizes by introduction to either unoccupied existing or constructed habitat, providing that the potential impact of fish predation is under control.

Translocation is a practice that should not be contemplated without due consideration to the genetic consequences of moving animals that may be adapted to specific locations (Burke 1991; Reinert 1991; Driscoll *et al.* 1994; Greer 1996). This calls for detailed genetic studies prior to attempts to translocate individuals over large distances. Despite this concern, there are many occasions when translocation is necessary to guard against catastrophe (e.g., disease, wildfire, drought) by increasing the number of occupied sites.

The concern about local adaptation can be overcome by limiting the distance over which frogs should be translocated until further information is available on the genetic structure of different populations. In many instances, it may be possible to construct suitable habitat for *L. aurea* within 1–2 km of occupied areas (e.g., Greer 1994). Adult *L. aurea* are known to move distances of several hundred metres away from breeding areas (G. Daly, pers. comm.; Murphy 1995; A. White, pers. comm.) and several hundred metres between breeding sites (White and Pyke 1996) but it is not known whether they will colonize habitat over greater distances. Although it is desirable to find this out, in some instances populations may be too small to take this risk and translocation (of tadpoles and/or metamorphs) would be appropriate. Experimental studies should investigate this because it may be useful for long-term management of *L. aurea*. Given the contraction in the range of *L. aurea*, translocation is recommended because many formerly occupied sites are now isolated (White and Pyke 1996) and may never be recolonized.

Regional Planning

An important consideration for endangered species is to ensure that viable populations are preserved throughout their geographic range (e.g., Murphy and Noon 1992). This is for two important reasons: i) to preserve genetically differentiated populations and, ii) to guard against catastrophic events eliminating populations. A regional approach is recommended for widespread species such as *L. aurea* where recovery should be attempted throughout the range rather than at a subset of sites that may be chosen due to non-biological factors as much as to biological ones.

The distribution of *L. aurea* in New South Wales can be divided into the following regional units for management: Far North Coast, Newcastle-Central Coast, Sydney North (north of the Parramatta River and Sydney Harbour), Sydney South (south of the Parramatta River and Sydney Harbour), Wollongong-Shoalhaven, Batemans Bay and Far South Coast. These seven regions could be delineated on the basis of their local government boundaries or based on geographic boundaries. This will require further consideration to determine the number and size of the regional units that are most appropriate for management. Any populations that may still occur on the Southern Tablelands and Northern Tablelands should be managed as additional units because these populations are likely to be genetically distinct.

The specific aim of the regional planning should be to preserve at least three fully isolated but viable populations per region. This number is arbitrary because no PVA has been conducted to assess this. However, it is generally accepted that preserving several viable populations is superior to a single viable population (Burke *et al.* 1991). Because these regional units are quite large and may include genetically distinct populations (see Colgan 1996), the populations designated as viable for management should be widely dispersed through the region if possible and could be determined by genetic studies. However, it should be emphasized that demographic and environmental influences pose a far greater threat to small populations than does genetic malfunction (see Caughley 1994) so an emphasis should be placed on managing sites with the potential to contain the largest population sizes.

Conserving *L. aurea* presents a different perspective to that for many endangered species because it will occupy highly disturbed sites where small areas of habitat are available for breeding. This trait can be used to increase the number of occupied sites in a region. For example, *L. aurea* will readily use dams on golf courses and presently occupies several in Sydney (A. White, pers. comm.). This situation could be put to advantage if golf course managers could be persuaded to retain some fish-free dams that could be colonized by or used as translocation sites for *L. aurea*. There is considerable potential here; Sydney alone contains 98 golf courses (UBD 1994). There are also areas of artificial and natural wetlands managed by municipal council's that contain apparently suitable habitat but which are typically inhabited by Mosquito Fish. Management within each regional unit should include the identification and mapping of as many areas of suitable habitat as possible and approaches made to the managers of such areas to determine those that may be sympathetic to the conservation needs of *L. aurea*.

Action Groups

It will require a considerable amount of organization, as well as time and money, to conserve *L. aurea* across approximately seven regional areas. This will require a group of interested people to be able to co-ordinate the conservation effort. It was proposed at the Green and Golden Bell Frog Conference that a Bell Frog Action Group be formed with an interested person nominated from each of several regions to keep track of activities in their region that involve *L. aurea*. Information on such activities would be sent to a central co-ordinator who would keep the members of the Action Group apprised of developments in other regions. This group should be involved with co-ordinating surveys for new locations, providing census data for population sizes, providing recommendations for management actions required at specific sites and providing nominations for sites to be managed as viable populations. The involvement of local community groups (e.g., Webster *et al.* 1995) is likely to be necessary to assist with research and monitoring of particular *L. aurea* populations and to prevent adverse human impacts.

CONCLUSION

Recovery plans and action statements have been prepared for several rare and geographically restricted frogs in southern Australia (e.g., Osborne 1991; Watson *et al.* 1991; Llewellyn and Osborne 1992; CNR 1993, 1994) but *L. aurea* is the first broadly distributed frog requiring similar attention. *Litoria aurea* is unusual among endangered species because it exhibits traits that are more suggestive of a species that should be abundant; it has a very high fecundity (among the highest of any *Litoria*), it often occupies disturbed and human-constructed habitats (disused brickpits, farm dams, golf course dams, industrial sites) and has an extensive geographic range. Despite these traits, *L. aurea* has gone from being common in the 1960s and 1970s to residing in a substantially reduced number of formerly occupied sites with low abundance (White and Pyke 1996). This has led to formal recognition as a threatened species (i.e., with the highest conservation status) in New South Wales.

The present study has identified further actions that are required for a detailed recovery plan on *L. aurea*. These include: 1. further study of habitat preference and habitat use; 2. further surveys of potential habitat; 3. studies to describe population dynamics; 4. experimental studies that aim to control the impacts of exotic fish predators; 5. a population viability analysis; 6. assessment of the role of translocation in the management of *L. aurea*; 7. conservation of *L. aurea* at a regional scale; 8. further assessment of genetic structure of populations; and 9. formation of an action group to co-ordinate recovery planning.

Because of the need for conservation to operate at a regional scale, it is possible that regional recovery plans could be prepared by interested individuals or groups and which could later feed into an overall recovery plan that applies throughout the species' range. This would enable conservation actions within a region to begin when adequate information is available for that region, without relying on the necessity for an overall recovery plan to be finalized before action can be taken.

Current legislation in New South Wales has prevented the destruction of this species' habitat at many locations and is likely to have prevented local extinction at several sites. However, it may require recognition by the Australian *Endangered Species Protection Act* 1992 to provide funding for the implementation of a recovery plan and to raise the profile of the conservation needs of this formerly common frog. The dramatic decline of the Green and Golden Bell Frog throughout New South Wales indicates that it is vulnerable to extinction.

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